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(71) Applicant(s)
Schlumberger Holdings Limited
(Incorporated in the British Virgin Islands)
P O Box 71, Craigmuir Chambers, Road Town, Tortola, British Virgin Islands

(72) Inventor(s)
Craig D Johnson
Matthew R Hackworth
David Wei Wang

(74) Agent and/or Address for Service
Brian D Stoole
WesternGeco Limited, Schlumberger House, Buckingham Gate, GATWICK, West Sussex, RH6 0NZ, United Kingdom

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(52) UK CL (Edition T)
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WPI Abstract Accession No. 2000-573960 & FR2790509 (see abstract)

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(54) Abstract Title
Control of flow into completion base pipe

(57) In lateral wellbores, the flow rate from the formation into the completion base pipe 28 is not always equal along the length of the completion. There tend to be higher flow rates at the 'heel' of the lateral wellbore, than at the 'toe'. By varying the effective area of fluid communication between the completion and formation, the flow rate can be more evenly distributed. Thee methods to achieve this variation in effective area of fluid communication are disclosed. The sizes of holes 30 or the number of holes 30 in the completion base pipe may be graduated along the length of the pipe, with smaller or fewer holes at the heel of the lateral borehole. In another embodiment, the completion comprises a base pipe 28 having holes 30 in its wall, and a screen 34 that surrounds the base pipe 28. Splines 38 are located between the base pipe and the screen, and a rod 40 is selectively insertable between adjacent splines 38 to selectively cover the holes 30 located an the base pipe 28 between the adjacent splines 38. In a third embodiment, a sleeve 44 having openings 48 in its wall is rotatably connected to the base pipe 28, such that rotation of the sleeve enables the alignment and misalignment of the holes 30 and openings 48.

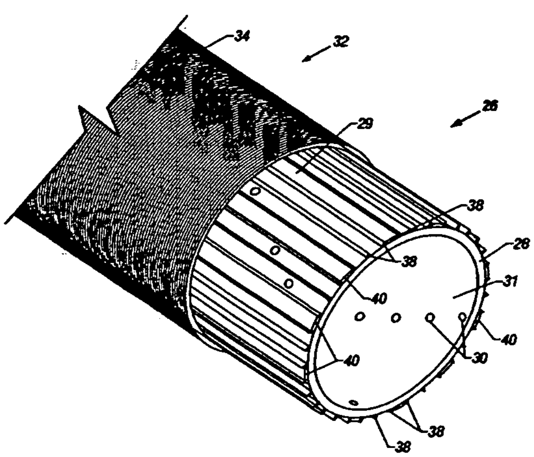

FIG. 7

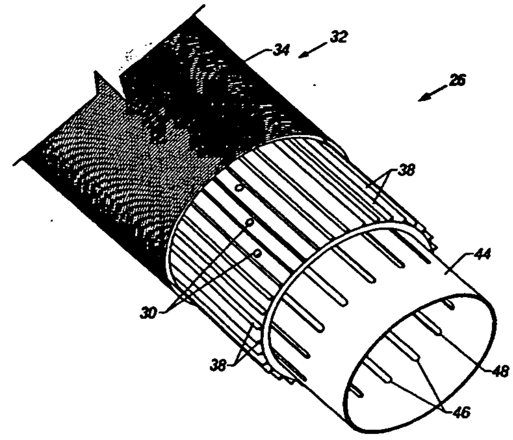

FIG. 8

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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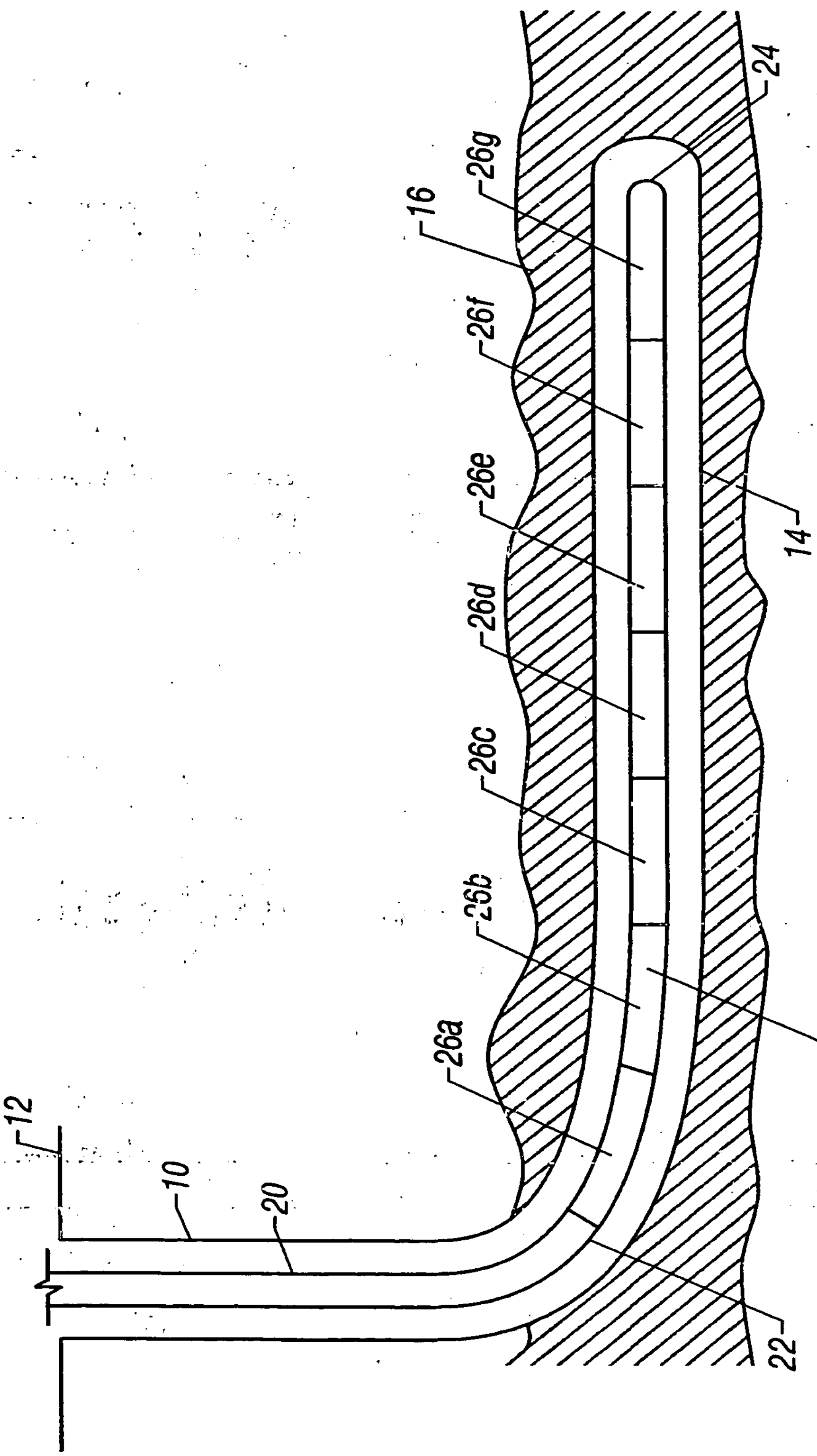

FIG. 1

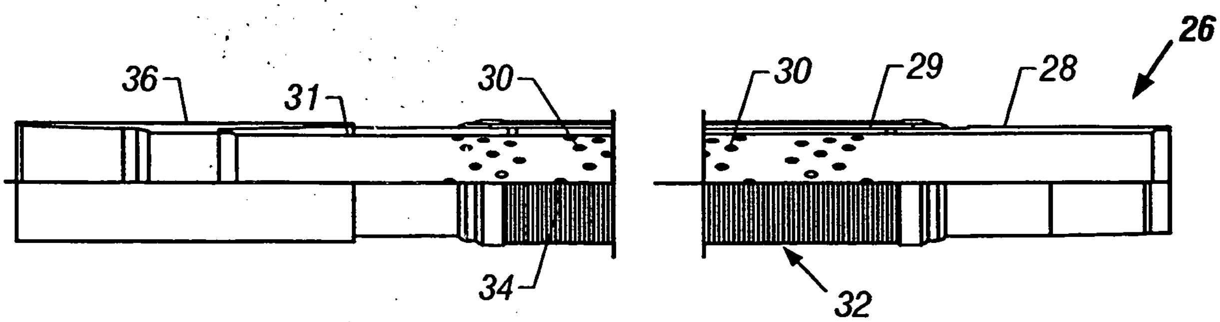

FIG. 2

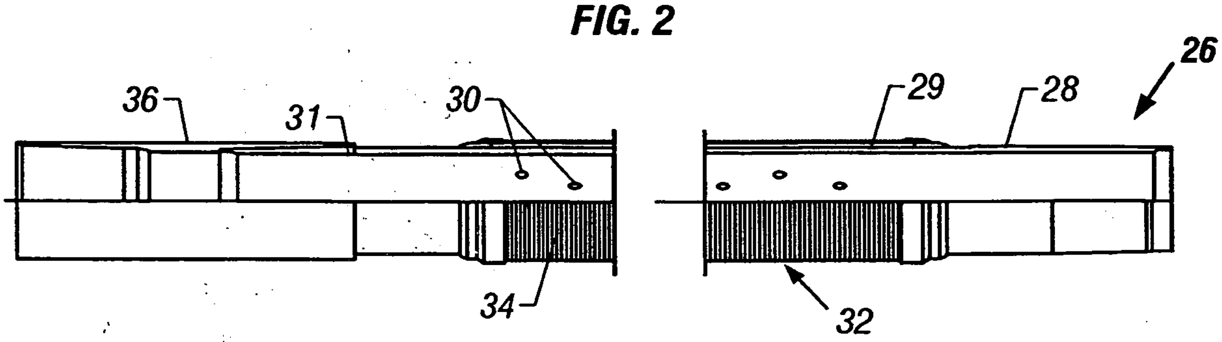

FIG. 3

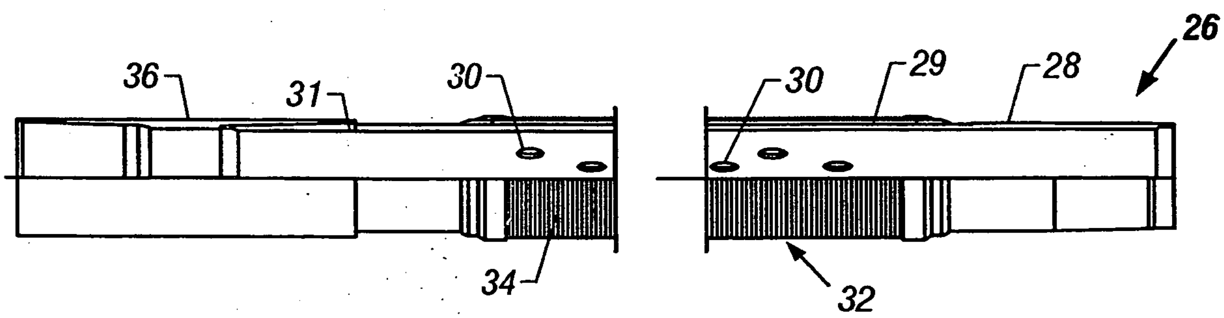

FIG. 4

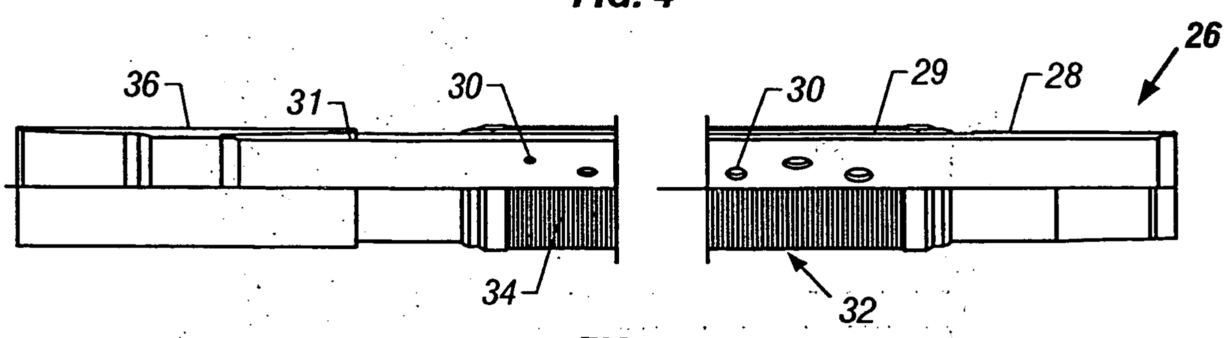

FIG. 5

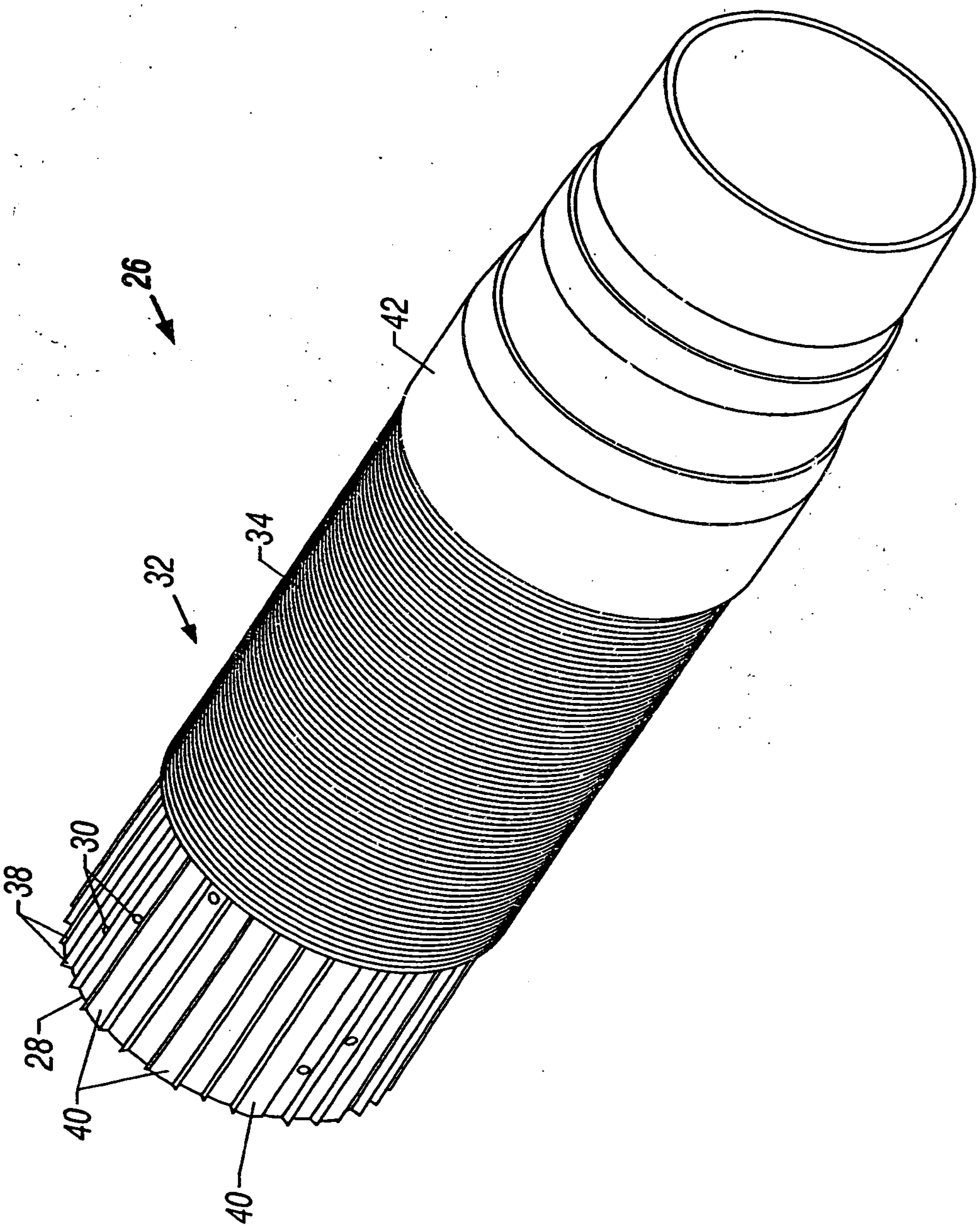

FIG. 6

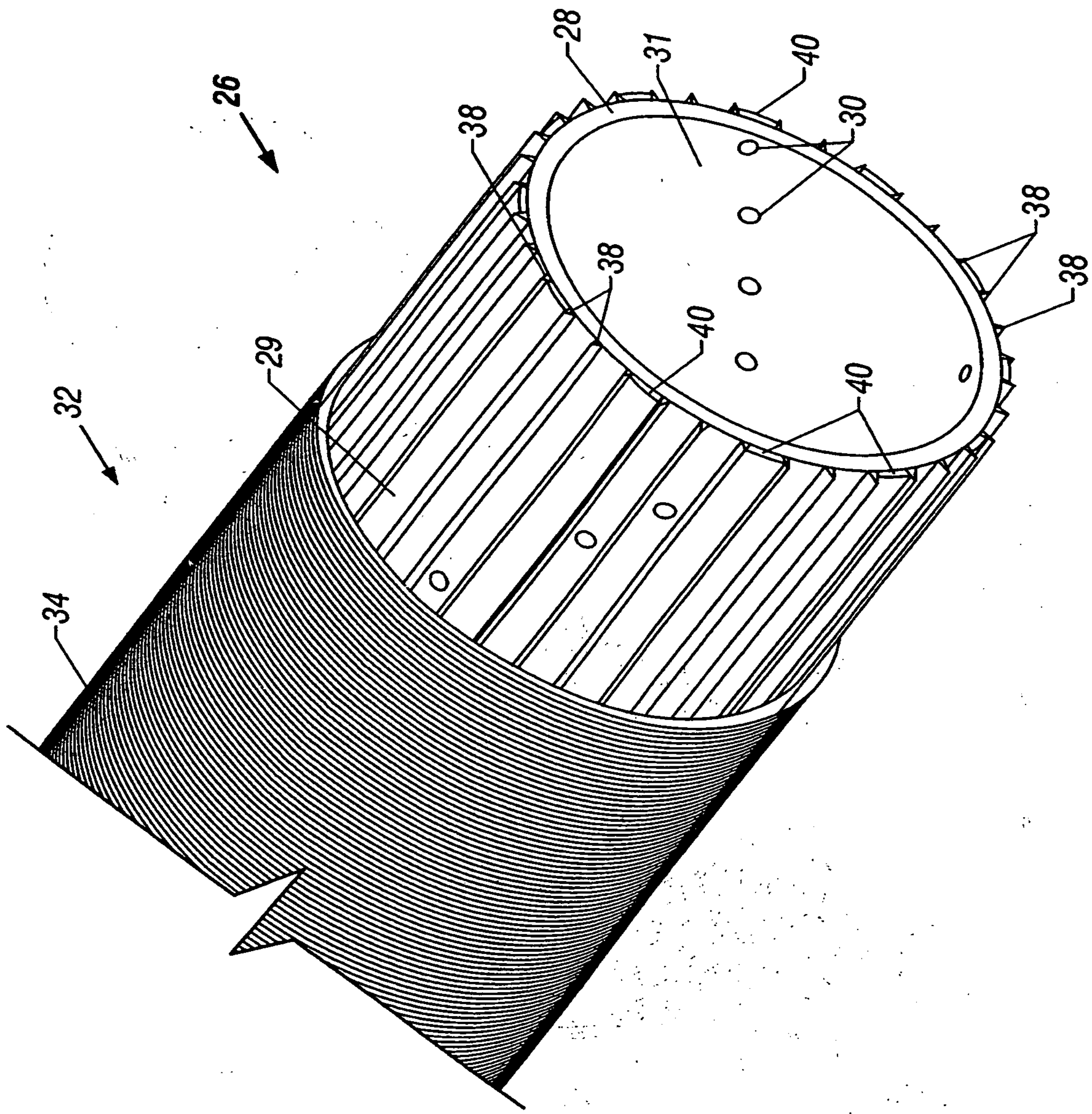

FIG. 7

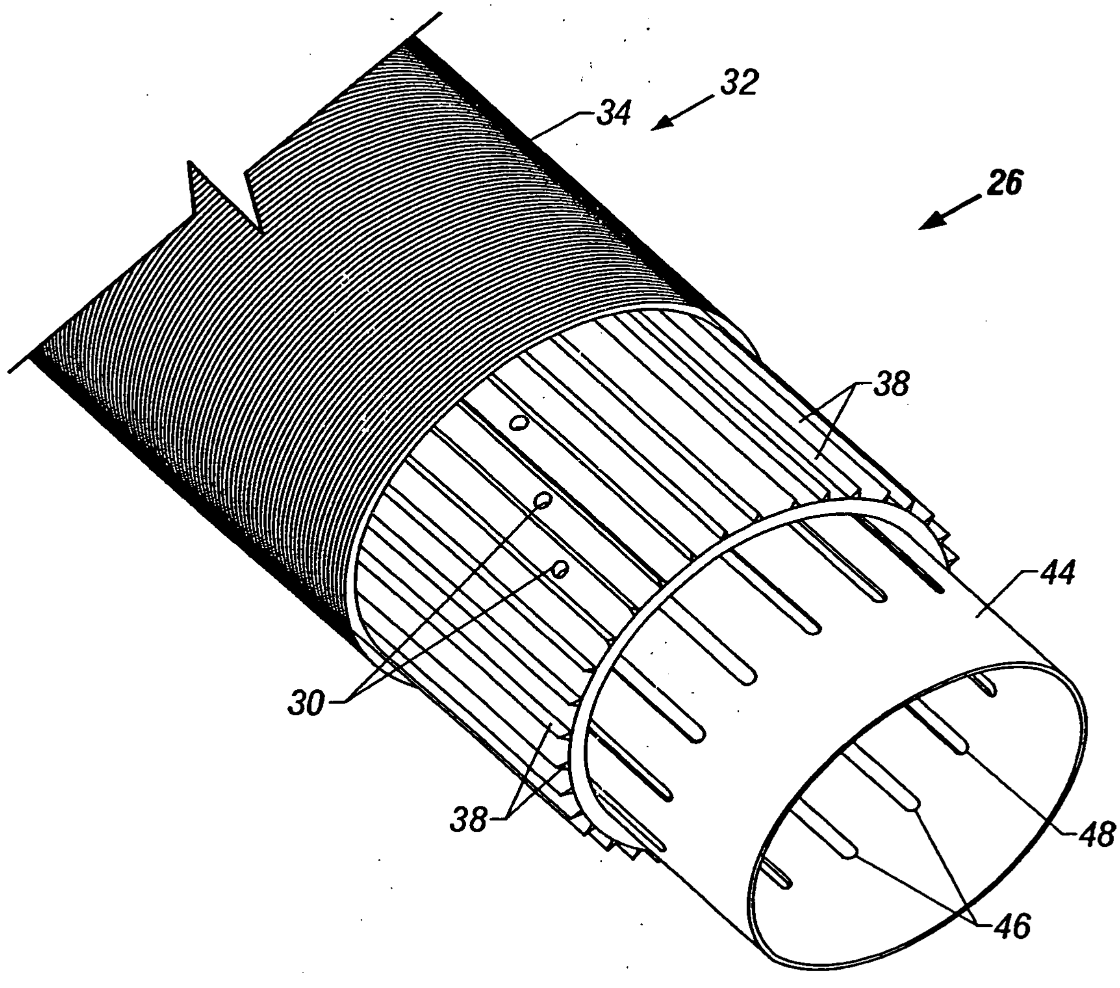

FIG. 8

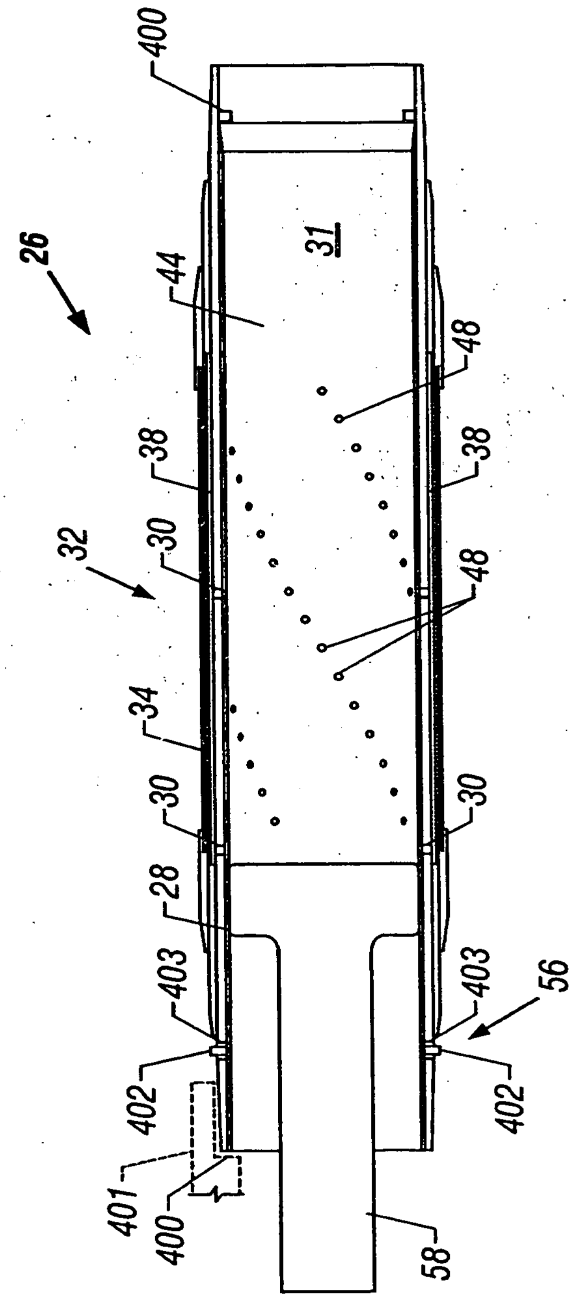
400
26
31
44
48
38
38
32
30
48
34
30
30
28
403
403
56
402
402
401
400
58

FIG. 9

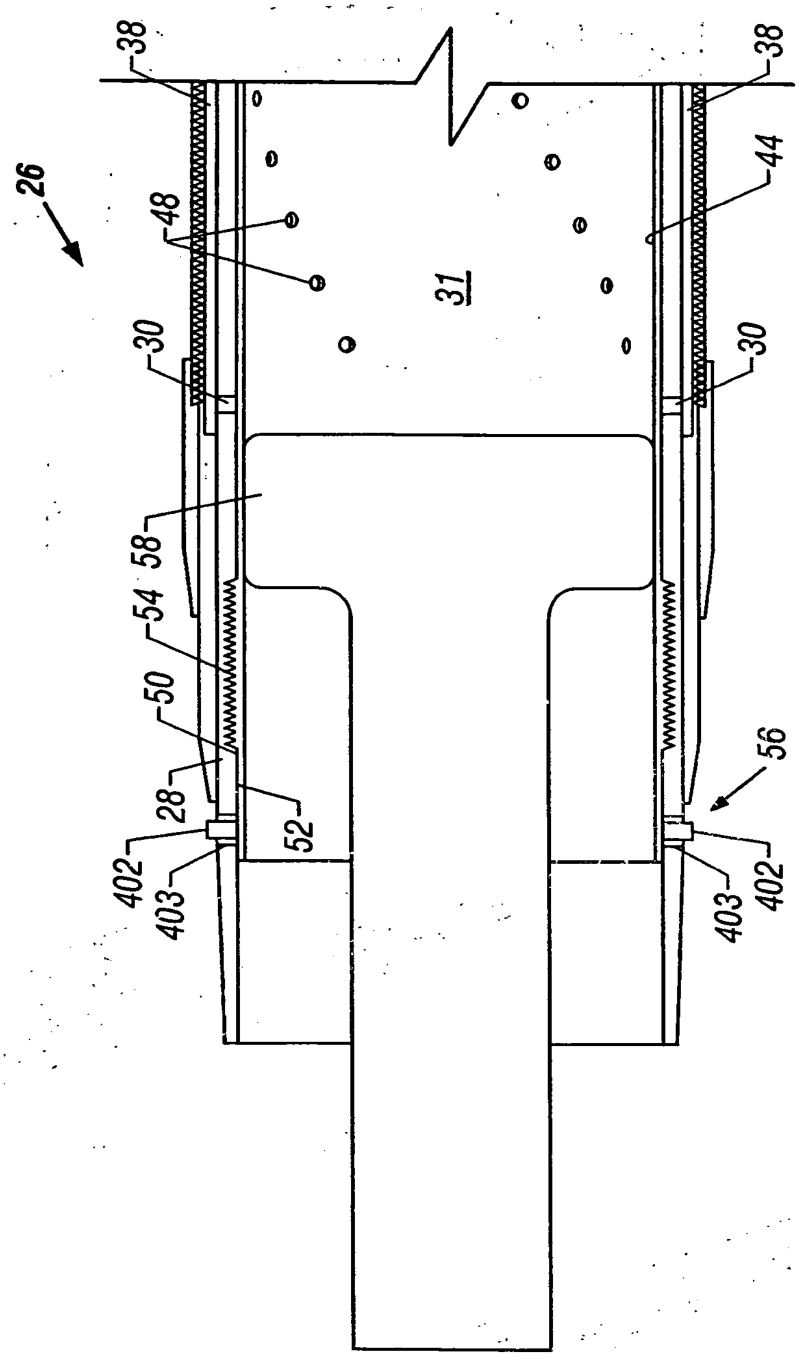

FIG. 10

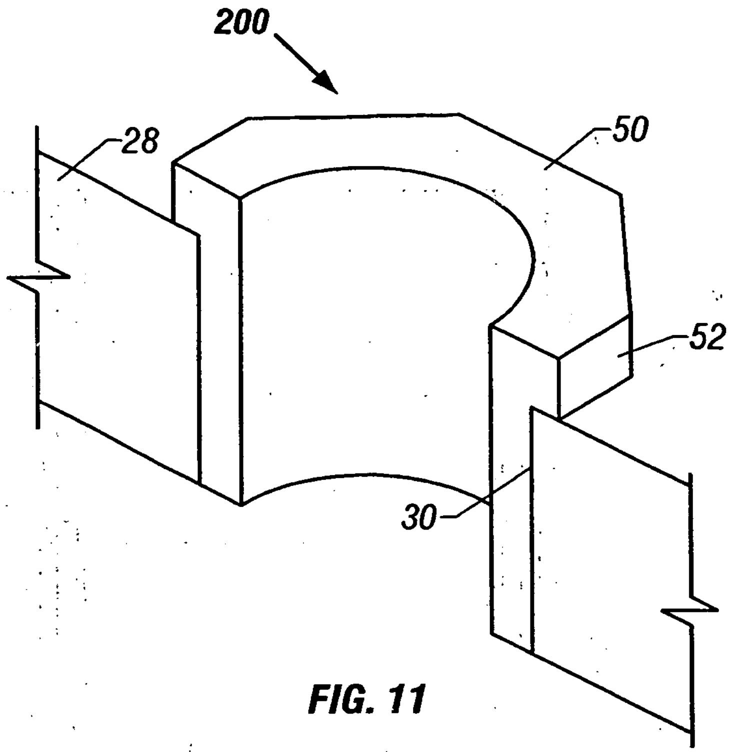

FIG. 11

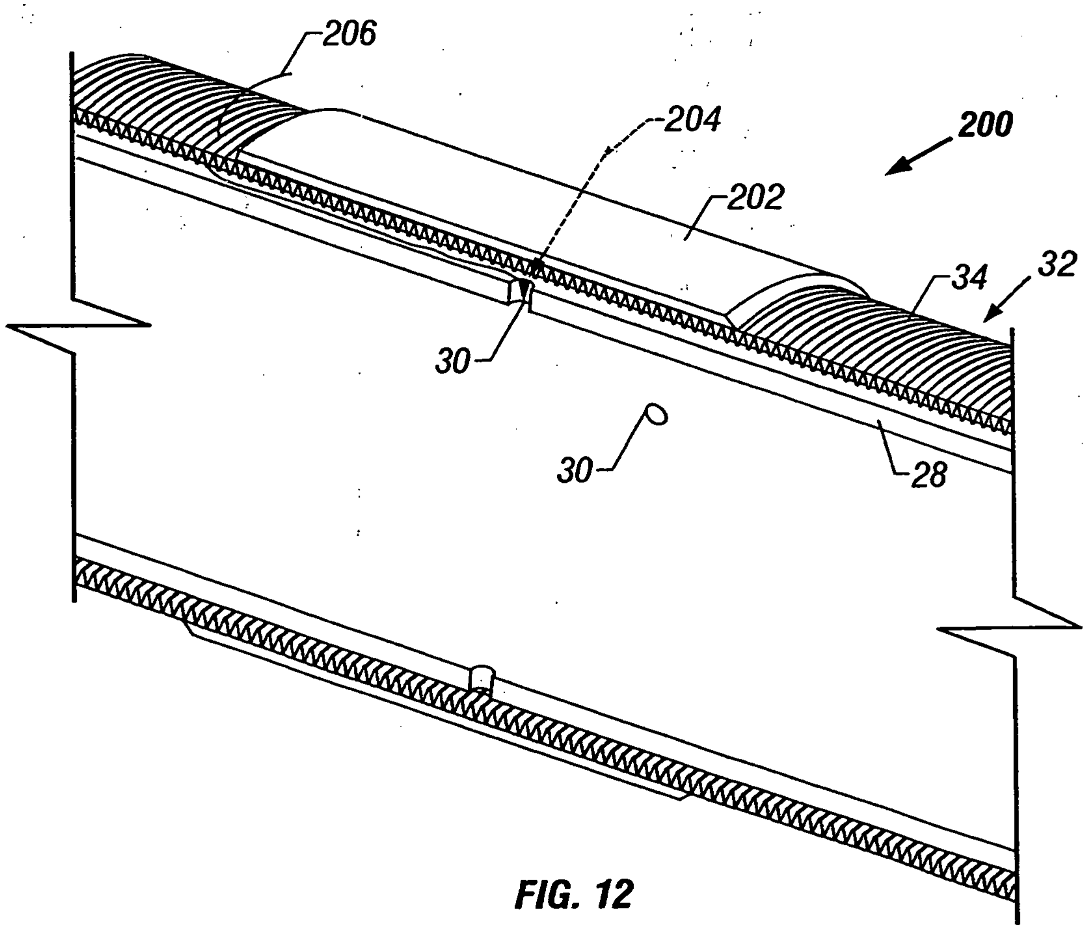

FIG. 12

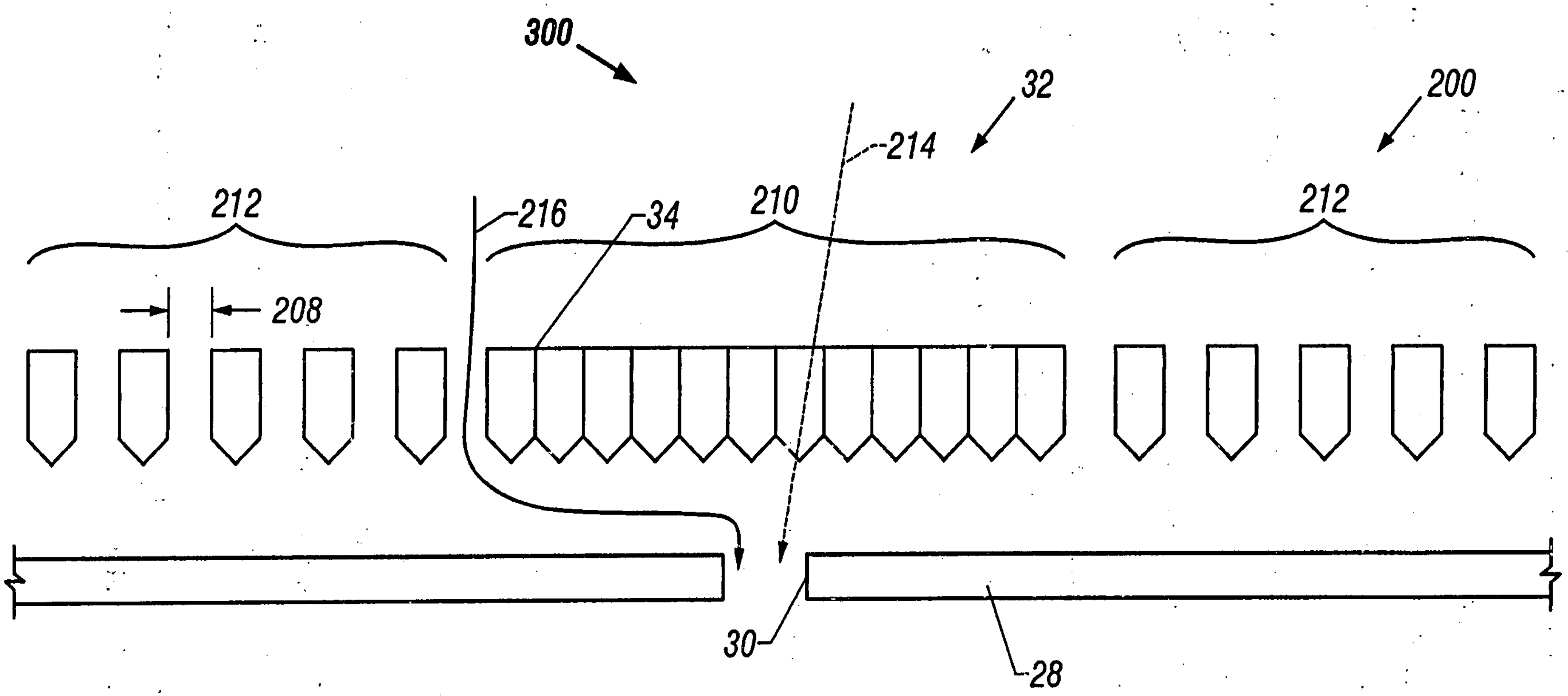

FIG. 13

BASE-PIPE FLOW CONTROL MECHANISM

BACKGROUND OF THE INVENTION

Field of Invention. This invention relates generally to flow control in downhole completions. Specifically, this invention relates to the control of flow along the length of a horizontal downhole completion.

Related Art. Within the oil and gas industry, it is now fairly common to include lateral wellbores that extend at an angle from a main vertical wellbore. In some cases, the lateral wellbores extend in a substantially horizontal direction from the main wellbore.

A completion is typically deployed within such lateral wellbores. The completion may include sliding sleeves, packers, and sand control equipment. Essentially, hydrocarbons flow from the formation intersected by the lateral wellbore, into the lateral wellbore, into the completion, and to the surface through the completion and associated tubing string.

However, in lateral wellbores, specially those extending in a substantially horizontal direction, the flow rate into the completion is not equal along the length of the completion. Instead, due to the flow friction along the length of the completion, a higher flow rate tends to exist at the near end or "heel" of the lateral completion, and a lower flow rate tends to exist at the far end or "toe" of the lateral completion. The disparity in flow rate from the "toe" to the "heel" of the lateral completion, in turn, may lead to premature gas or water coning at the area of higher flow rate and/or may also decrease the total amount of hydrocarbons extracted from the relevant formation.

The prior art would therefore benefit from a system and method for equalizing the flow rate along a lateral completion.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an elevational view of a lateral wellbore extending from a main wellbore, with a completion deployed therein, and generally utilizing the invention.

Figure 2 is a partial cross-sectional view of a completion section that illustrates the first embodiment of this invention.

Figure 3 is a partial cross-sectional view of another completion section that illustrates the first embodiment of this invention.

Figure 4 is a partial cross-sectional view of another completion section that illustrates the first embodiment of this invention.

Figure 5 is a partial cross-sectional view of another completion section that illustrates the first embodiment of this invention.

Figure 6 is a partial cut-away view of a completion section that illustrates the second embodiment of this invention.

Figure 7 is a more detailed partial cut-away view of a completion section that illustrates the second embodiment of this invention.

Figure 8 is a partial cut-away view of a completion section that illustrates the third embodiment of this invention.

Figure 9 is a cross-sectional view of a completion section that illustrates the third embodiment of this invention.

Figure 10 is a more detailed cross-sectional view of one end of the completion section that illustrates the third embodiment of this invention.

Figure 11 is an isometric, cut-away view of an insert that can be included in the holes that extend through the completion sections of this invention.

Figure 12 is an isometric, cut-away view of a completion section including one embodiment of an erosion barrier.

Figure 13 is a cross-sectional view of a completion section including another embodiment of an erosion barrier.

DETAILED DESCRIPTION

Figure 1 generally illustrates a main wellbore 10 extending from the surface 12 downwardly. A lateral wellbore 14 extends from the main wellbore 10 and intersects a hydrocarbon formation 16. A completion 18 extends within the lateral wellbore 14 and includes a "toe" 24 at the far end of the completion 18 and a "heel" 22 at the near end of the completion 18. The completion 18 is connected to, for instance, tubing string 20 that extends within the main wellbore 10 to the surface 12.

As previously discussed, without incorporating additional elements, due to the flow friction along the length of the completion 18, the flow rate into the lateral completion 18 at the heel 22 of the completion 18 is greater than the flow rate at the toe 24 of the completion 18. This

invention evenly distributes the flow rate into the completion 18 by controlling the pressure drop into the completion 18 along the length of the lateral completion 18. This is achieved by varying the effective area of fluid communication between the completion 18 and the formation 16 (hereinafter referred to as the "Effective Area of Fluid Communication") along the length of the completion 18. In principle and all variables being equal, a completion section with a larger Effective Area of Fluid Communication will have a higher flow rate than a completion section with a smaller Effective Area of Fluid Communication. It is noted that a decrease in the Effective Area of Fluid Communication for a completion section results in an increase in pressure drop across such completion section, and vice-versa.

Essentially, the completion 18 is divided into sections 26(a-g) from the heel 22 to the toe 24, and the sections 26 are constructed so that the Effective Area of Fluid Communication for each section 26 increases from the section 26a closest to the heel 22 to the section 26g closest to the toe 24. Once calculated correctly, an increase of the Effective Area of Fluid Communication from the heel 22 to the toe 24 offsets (compensates for) the disparity in flow rate previously discussed, thereby evenly distributing the flow rate along the length of the completion 18. In one embodiment, such increase is a gradual increase. Three embodiments for the present invention are set forth herein.

First Embodiment

Figures 2-5 show the first embodiment of the invention. In this embodiment, each section 26 includes a base pipe 28 that has holes 30 extending therethrough. Each section 26 may also include a filter 32, such as a sand screen 34. Sections 26 may be coupled to each other by threaded couplings 36, for example. Hydrocarbon from the formation 16 typically flows from the formation 16, into the lateral wellbore 14 (through perforations if included), through the filter 32 (if included), into the annular region 29 formed between the filter 32 and the base pipe 28, through the holes 30, into the central bore 31 of the lateral completion 18, and up to the surface 12 through the tubing string 20.

This embodiment comprises varying the number and/or size of the holes 30 for each section 26 so that an increase (a gradual increase in one embodiment) in the Effective Area of Fluid Communication (through the holes 30) can be achieved from the heel 22 to the toe 24 of

the completion 18. Thus, the aggregate hole 30 area for each section 26 increases from the heel 22 to the toe 24 of the completion 18.

Figure 2 shows a section 26 with a certain number of holes 30. Figures 3 -5, comparatively, include sections 26 with a lesser number of holes 30 than shown in Figure 2. Between Figures 3-5, it is noted that the size of the holes 30 of Figure 3 are smaller than the size of the holes 30 of Figure 4 and that the size of the holes of Figure 5 increases from left to right.

The sections 26 shown in Figures 2-5 can be arranged in a variety of ways to achieve the objective of providing a gradual increase in the Effective Area of Fluid Communication from heel 22 to the toe 24 of completion 18. For instance, the sections 26 can be arranged so that section 26a has less holes 30 than section 26g and so that the number of holes 30 for each adjacent section 26(a-g) increases from section 26a to section 26g. Or, the sections 26 can be arranged so that the holes 30 of section 26a are smaller than the holes 30 of section 26g and so that the size of the holes 30 for each adjacent section 26(a-g) increases from section 26a to section 26g. Or, several sections 26 as shown in Figure 5 may be used, wherein the sizes of the holes 30 not only increase from heel 22 to toe 24 from section 26 to section 26, but also increase within each section 26. The sections 26 can also be arranged so that the number as well as the size of the holes 30 increase from heel 22 to toe 24.

Second Embodiment

A second embodiment of the invention is shown in Figures 6 and 7, which for purposes of clarity are cut away views and do not show the entire section 26. In this embodiment, each section 26 also includes a base pipe 28 that has holes 30 extending therethrough. Each section 26 may also include a filter 32, such as a sand screen 34. Sections 26 may be coupled to each other by threaded couplings 36, for example. As is known in the art, a plurality of splines 38 typically provide support between the sand screen 34 and the base pipe 28. The splines 38 normally extend longitudinally along the length of the base pipe 28 and are spaced apart about the circumference of the base pipe 28. The holes 30 provide fluid communication from the area between the splines 38 to the central bore 31 of the base pipe 28. Thus, hydrocarbon from the formation 16 typically flows from the formation 16, into the lateral wellbore 14 (through perforations if included), through the filter 32 (if included), into the annular region 29 formed

between the filter 32 and the base pipe 28, through the holes 30, into the central bore 31 of the lateral completion 18, and up to the surface 12 through the tubing string 20.

In this embodiment, however, the number of holes 30 that provide such fluid communication can be modified by inserting a bar 40 between adjacent splines 38 so that such bar 40 covers the holes 30 located between such adjacent splines 38. Thus, the insertion of a bar 40 changes the number of holes 30 that provide fluid communication (thus changing the Effective Area of Fluid Communication through such section 26), thereby enabling an operator to change the pressure drop (and therefore flow rate) across each section 26. Of course, more than one bar 40 can be inserted in each section 26, each being inserted between different pairs of adjacent splines 38.

The bars 40 can be machined to a close tolerance to snugly fit between adjacent splines 38. Bars 40 can also be different lengths, thereby covering different numbers of holes 30. Bars 40 are constructed so that flow through a rod-covered hole 30 is severely restricted or altogether blocked.

The bars 40 can be inserted between the splines 38 either at the assembly facility or at the rig floor. To allow for simple insertion and removal at either site, each section 26 includes at least one end cap 42 that is easily selectively removed from the remainder of the section 26 thereby allowing access to the bars 40 and splines 38. Such end caps 42 may be attached to the base pipe 28 by mechanisms such as threading or clamping.

In use, bars 40 can be selectively inserted between adjacent splines 38 of the sections 26(a-g) so that the Effective Area of Fluid Communication (the aggregate hole 30 area) for each section 26 is controlled by the operator. In this manner, an operator can arrange the sections 26(a-g) to achieve the objective of providing an increase (a gradual increase in one embodiment) in the Effective Area of Fluid Communication from the heel 22 to the toe 24 of completion 18. For instance, given the same pattern, number, and size of holes 30 for each section 26, a decrease in the number of bars 40 used from section 26a to section 26g results in an increase in the Effective Area of Fluid Communication from the heel 22 to the toe 24 of completion 18.

It is noted that the bars 40 are not restricted to be used with only wire wrapped sand control screens. Their use can also be implemented with any screen that has an annular space between the base pipe and filter (screen).

Third Embodiment

A third embodiment of the invention is shown in Figures 8-10, which for purposes of clarity are cut-away and cross-sectional views and do not show the entire section 26. In this embodiment, each section 26 also includes a base pipe 28 that has holes 30 extending therethrough. Each section 26 may also include a filter 32, such as a sand screen 34. Sections 26 may be coupled to each other by threaded couplings 36, for example. As is known in the art, a plurality of splines 38 typically provide support between the sand screen 34 and the base pipe 28. The splines 38 normally extend longitudinally along the length of the base pipe 28 and are spaced apart about the circumference of the base pipe 28. The holes 30 provide fluid communication from the area between the splines 38 to the central bore 31 of the base pipe 28. Thus, hydrocarbon from the formation 16 typically flows from the formation 16, into the lateral wellbore 14 (through perforations if included), through the filter 32 (if included), into the annular region 29 formed between the filter 32 and the base pipe 28, through the holes 30, into the central bore 31 of the lateral completion 18, and up to the surface 12 through the tubing string 20.

In this embodiment, however, the number and/or area of holes 30 that provide such fluid communication can be modified by rotation of a sleeve 44. The sleeve 44 can be located internally of the base pipe 28. The sleeve 44 includes openings 48 therethrough (which may be in the form of slots 46 – see Figure 8) that, depending on the position of the sleeve 44, line up with the holes 30 of the base pipe 28. The sleeve 44 can be rotated so that alignment of the openings 48 and the holes 30 can be varied, thereby modifying the Effective Area of Fluid Communication through each section 26.

To enable the rotational movement of the sleeve 44 within the base pipe 28, the outer surface 50 of the sleeve 44 is rotatably connected to the inner surface 52 of the base pipe 28. In one embodiment as shown in Figure 10, the sleeve 44 is rotatably connected to the base pipe 28 by way of mating threads 54. Mating threads 54 can be included on one end of the sleeve 44 (as shown in Figure 10), on both ends of sleeve 44, or along a large portion or the entirety of the outer surface 50 of sleeve 44. In another embodiment as shown in Figure 9, the sleeve 44 may be slip-fitted within the base pipe 28 to allow their relative rotation. In this embodiment, axial movement of the sleeve 44 may be prevented by stops 400 protruding from the inner surface 52

of the base pipe 28. As shown in Figure 9 on one of the ends of section 26, the stops 400 may comprise a threaded connector 401 used to connect two sections 26 together.

The sleeve 44 includes a selective locking mechanism 56 that enables the sleeve 44 to be locked (not rotatable) at different positions, each position allowing a different Effective Area of Fluid Communication through each section 26 (as previously discussed). The locking mechanism 56 can comprise, for example, set screws 402 threaded through set screw holes 403 of the base pipe 28 against the sleeve 44 to thereby prevent rotation of the sleeve 44. In another embodiment (not shown), the locking mechanism 56 can comprise an indexing ratchet mechanism.

The sleeve 44 can be rotated between positions at the assembly facility or at the rig floor. Once the section 26 is assembled, rotation of the sleeve 44 can be accomplished by the insertion of another tool 58 into the central bore 31. The tool 58 extends to the exterior of the section 26 so that the tool 58 can be easily manipulated by an operator. The tool 58 is selectively attached to the inner surface 60 of the sleeve 44, such as by mating threads or a mating profile (not shown). Once attached to the sleeve 44, the tool 58 is rotated by the operator to achieve the desired position between the openings 48 and the holes 30.

In use, the sleeves 44 can be rotated within the base pipes 28 of sections 26(a-g) so that the Effective Area of Fluid Communication (the aggregate hole 30 area) for each section 26 is controlled by the operator. In this manner, an operator can arrange the sections 26(a-g) to achieve the objective of providing an increase (a gradual increase in one embodiment) of the Effective Area of Fluid Communication from the heel 22 to the toe 24 of completion 18. For instance, the sleeve 44 of each section 26 can be positioned so that the Effective Area of Fluid Communication for the sections 26 (a-g) increases from the heel 22 (section 26a) to the toe 24 (section 26g) of completion 18.

<u>Combination of Embodiments</u>

It is noted that the three embodiments previously described may be combined in the same completion 18. For instance, in the same section 26, the holes 30 can be varied in size and/or number (first embodiment) in combination with the use of the bars 40 (second embodiment) or the sleeve 44 (third embodiment). In addition, each section 26(a-g) may also comprise a different one of the of the three embodiments so that, for instance, the first embodiment is used

in section 26a, the second embodiment is used in section 26b, and the third embodiment is used in section 26c.

Additional Optional Elements

Figures 11 –13 show different embodiments of erosion inhibitors 200 that may be used with any of the embodiments previously described. It is noted that increasing the pressure differential across the base pipe holes 30 (by decreasing the Effective Area of Fluid Communication) leads to increased fluid velocity through the remaining holes 30. In turn, an increase in fluid velocity through base pipe holes 30 has been shown to erode the walls of the holes 30, which is of course undesirable. Moreover, an increase in fluid velocity may also erode the filter 32 or screen 34 through which such fluid is passing.

Turning to Figure 11, to prevent such erosion on the walls of the holes 30, the erosion inhibitor 200 can comprise a hardened insert 50 that can be inserted in each hole 30. The insert 50 can be made of carbide, for example, or any other sufficiently hard and long-lived material. Each insert 50 is generally disc shaped to enable the fluid communication of hydrocarbons therethrough and is secured within its relevant hole 30 by means known in the art, such as welding, brazing, gluing, threading, or mechanical interference fit.

It is noted that the insert 50 shown in Figure 11 includes a shoulder portion 52. Instead of shoulder portion 52, some inserts 50 may be flush with the base pipe 28 inner and outer surfaces.

Figure 12 illustrates an erosion inhibitor 200 that helps to prevent erosion of the filter 32 (screen 34) and the walls of the holes 30. The erosion inhibitor 200 comprises a shield 202 attached to the exterior of the filter 32, such as by latching or welding. In one embodiment, the shield 202 surrounds the holes 30. The shield 202 prevents the fluid from flowing directly across the filter 32 and though the holes 30 (see dashed flow path 204), which can lead to erosion of either/both due to the high velocity of the fluid. Instead, the fluid must flow around the shield 202, through the filter 32, and through the holes 30 (see flow path 206). The path taken by the fluid around the shield 202 lowers the velocity of the fluid and thus aids in preventing erosion. Of course, more than one shield 202 can be included on each completion section 26.

Figure 13 illustrates another embodiment of an erosion inhibitor 200 that helps to prevent erosion of the filter 32 (screen 34) and the walls of the holes 30. The erosion inhibitor 200 can

comprise a specially designed screen 300 that includes a non-permeable screen section 210 and normal screen sections 212. In one embodiment, non-permeable screen section 210 surrounds the holes 30. Non-permeable section 210 does not include gaps and therefore prevents fluid from flowing therethrough. Normal sections 212 include the typical gaps 208 in such filters which allow fluid flow therethrough. The screen 300 (non-permeable section 210) prevents the fluid from flowing directly across the filter 32 and though the holes 30 (see dashed flow path 214), which can lead to erosion of either/both due to the high velocity of the fluid. Instead, the fluid must flow around the non-permeable section 210, through the gaps 208 of the normal sections 212, and through the holes 30 (see flow path 216). The path taken by the fluid around the non-permeable section 210 lowers the velocity of the fluid and thus aids in preventing erosion. Of course, more than one non-permeable section 210 can be included on each completion section 26

It is noted that the different embodiments of the erosion inhibitor 200 can be combined. Thus, inserts 50 can be used on the same section 26 (or completion 18) as the shield 202 or special screen 300. Moreover, the shield 202 and the special screen 300 can be used on the same section 26 (or completion 18).

It is to be understood that the invention is not limited to the exact details of construction, operation, exact materials or embodiments shown and described, as obvious modifications and equivalents will be apparent to one skilled in the art. Accordingly, the invention is therefore to be limited only by the scope of the appended claims.

CLAIMS

1. A section of a completion deployed within a lateral wellbore, comprising:
a base pipe including at least one hole therethrough;
a screen that surrounds the base pipe;
a plurality of splines located between the base pipe and the screen; and
a rod selectively insertable between adjacent splines to selectively cover the holes located on the base pipe between the adjacent splines.

2. A section of a completion deployed within a lateral wellbore, comprising:
a base pipe including at least one hole therethrough;
a sleeve rotatably connected to the base pipe; and
the sleeve including at least one opening therethrough;
wherein the rotation of the sleeve enables the alignment and misalignment of the holes and openings.

Application No: GB 0201219.3
Claims searched: 1
Examiner: Kathryn Orme
Date of search: 7 May 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1F (FLK, FLM, FJB, FJF, FLW, FMU)

Int Cl (Ed.7): E21B 34/14, 41/00, 43/08, 43/12, 43/14

Other: Online: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2343468 A (BAKER HUGHES) see whole document	
A	GB 2320938 A (HALLIBURTON ENERGY SEVICES) see whole document	
A	WPI Abstract Accession No. 2000-573960 & FR 2790509 (Schlumberger Services) 08/09/2000 (see abstract)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.